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RESEARCH MEMORANDUM

PRELIMINARY TANK TESTS OF NACA HYDRO-SKIS FOR HIGH-SPEED AIRPLANES

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SUMMARY

The results from tank landing and take-off tests with a dynamic model of a hypothetical jet-propelled airplane equipped with NACA hydro-skis are presented. These results show stable take-offs and landings for the model, although the resistance is found to be high. The high resistance, which is not considered necessarily inherent, appears to be acceptable for airplanes equipped with rocket motors. Consideration of several problems incidental to practical applications of hydro-skis leads to the conclusion that solutions for these problems can be obtained. It is concluded that hydro-skis suitable for flush retraction into streamline fuselages offer a practicable means for taking off and landing high-speed airplanes on the water.

INTRODUCTION

Jet propulsion offers an opportunity for eliminating the troublesome propeller from water-based airplanes and, thus, enables radical changes to be made in high-speed seaplanes. In order to take advantage of the opportunities thus opened for the seaplane, the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics has embarked on a hydrodynamic research program designed to explore these potentialities by several new approaches. The results of tests made to investigate one approach which shows marked possibilities are covered in this paper.

The approach is based on the idea of using retractable planing surfaces below the main body of the airplane. These planing surfaces, called hydro-skis, allow the high-speed part of the take-off and landing run to be made on simple surfaces of relatively small area and, thus, the main body of the airplane would not be subject to high water loads. The most conveniently retractable type of hydro-ski would have a bottom of such shape that when retracted it would form a continuation of the surrounding surface of the airplane. Such a convenience is of special interest in the design of high-speed aircraft, because of the difficulty of finding room for the retraction of wheels within the thin wings and small fuselages that are essential to high performance in such aircraft.

In the present work, the possibility of making take-offs and landings with hydro-skis was examined in Langley tank no. 2, using the $\frac{1}{12}$-size dynamic model of a hypothetical transonic airplane described in reference 1. A number of arrangements of hydro-skis merit consideration; however, the present tests were limited to twin-ski configurations. Several twin-ski configurations were partially investigated, and complete take-off and landing characteristics were obtained for one arrangement (figs. 1 and 2).

TESTING PROCEDURE

Landing tests were made with a number of hydro-ski configurations, the effect of changing the longitudinal position of each being investigated to some extent. The first tests were made with simple flat planing surfaces of rectangular plan form. Then, changes in plan form to improve the landing characteristics were made. Hydro-skis with the improved plan form, but curved in cross section to permit flush retraction in the fuselage, were then tested. When an arrangement with curved hydro-skis had been found that would give satisfactory landing characteristics, take-off tests were made with this configuration. In order to improve take-off characteristics, it was found necessary to double the original area of the hydro-skis. Subsequently, the landing characteristics of the hydro-skis with increased area were determined. The results of the take-off and landing tests of this configuration (figs. 1 and 2) are those presented.

The landing tests were made at a weight of 8720 pounds (full size) corresponding to a landing with most of the fuel expended. The take-off tests were made with a gross weight of 13,140 pounds.

The landing tests were made by landing the model as a free body from the Langley tank no. 2 monorail catapult. Landings with the flaps down 20° were made at trims of 8° and 12° with respect to the longitudinal axis of the model. At 8° trim the landing speed corresponded to 127 miles per hour (full size) and at 12° trim to 123 miles per hour. Motion pictures and visual observations were made of the landing tests. The length of landing runs was observed and measurements of longitudinal and normal accelerations were made with an accelerometer developed for model ditching tests. This accelerometer was placed $8\frac{1}{2}$ feet (full size) forward of the center of gravity at a point corresponding to a location suitable for the pilot's cockpit. The accelerometer was a single-component type and, in order to measure two components, it was necessary to repeat landings with the accelerometer rotated. Although the accelerometer recorded a time history, its running time was not sufficient to cover the complete landing runs; thus, a time history of the accelerations was determined only for the first part of the landings. (The maximum values after the accelerometer had stopped were, however, recorded.)

The setup for the take-off tests is shown in figure 3, which shows the model floating at take-off load. In these tests, the model was towed from its center of gravity about which it was free to trim. It was also free to rise. All controls were fixed and no external damping was applied. Resistance, trim, and rise of the center of gravity were measured during constant-speed runs. The resistance included the air drag of the complete model. Tests were made with flaps at 0° and deflected down 20°. The elevator was deflected up 30°, because the controls could not be varied during the test runs and this position of the elevator gave practical trims near take-off speed. Some accelerated runs from rest to take-off were made for additional observations of behavior.

RESULTS AND DISCUSSION

Landing Tests

Sequence photographs of a typical landing are shown in figure 4. After touching the water, the model maintained a very straight course and planed on the hydro-skis until near the end of the run when it trimmed up gradually until the rear part of the fuselage touched the water. At about 25 miles per hour (full size) the skis submerged leaving the model supported by the buoyancy of the fuselage and wings. In some landings the model made a slight bounce at the first contact but there was never more than one such bounce and there was no violent behavior associated with it. When the model was inadvertently landed on one ski, it would right itself and continue on a straight course down the tank, seldom deviating more than 10 feet from course in landing runs exceeding 2400 feet (full size). A few landings made in small waves (up to 2 feet high, full size) showed no great change in landing behavior from the smooth-water landings.

Typical records of normal accelerations for the first part of the landing runs are shown in figure 5. In calm water the maximum normal acceleration was 2.0g and waves 1.5 feet high did not cause an increase in this value. These small waves introduced a succession of small peak accelerations that were considerably lower than the maximum acceleration encountered on the initial impact. Although not shown, the maximum value of normal acceleration that occurred during the part of the run in which the hydro-skis submerged was about 0.3g.

The longitudinal decelerations were so small that the accelerometer did not give an adequate time history of them. Maximum longitudinal decelerations were about 0.5g in both calm and slightly rough water. Average longitudinal decelerations computed from the lengths of landing runs were about 0.25g. Waves 1.5 feet high (full size) caused about 5-percent increase in the average longitudinal decelerations.

Landings at the 8° and 12° attitudes were very similar. The principal change in landing behavior was a decrease in the length of landing run due to the decrease in landing speed accompanying the increase in trim from 8° to 12°. However, the decelerations were approximately the same for both trims.

An appreciable variation in landing behavior was obtained by varying the longitudinal position of the hydro-skis. When placed very far forward, the hydro-skis caused the aft part of the fuselage to enter the water at high speeds. As the hydro-skis were progressively moved aft, the length of landing runs was increased and the landing stability was improved. However, as would be expected, when the skis were moved too far aft they tended to throw the nose in. The longest and smoothest landing runs were obtained with the hydro-skis set just forward of the point where they would cause the model to nose in. The hydro-skis in figure 1 are shown at the position which gave the maximum length of landing run without danger of nosing in.

Considerably smaller hydro-skis than those shown gave satisfactory landings, although their take-off characteristics were poor. Hydro-skis of one-half the area of those shown gave relatively smooth landings with only slight increases in accelerations. They submerged at a speed approximately 5 miles per hour higher than the large ones.

Hydro-skis of rectangular plan form resulted in landings less smooth then those given by the hydro-skis shown. It would be expected that the pointed trailing edge would tend to lower the normal accelerations but in a limited number of measurements no substantial decrease in maximum normal acceleration was obtained.

The hydro-skis shown in figure 1 were set so that the midradii of the skis are vertical. When the hydro-skis were rotated about a longitudinal axis so that the midradii intersect on the axis of the fuselage, it was found that the landings became unstable in roll.

Take-Off Tests

Sequence photographs of the model taking off are shown in figure 6. Plots of resistance, trim, and rise against speed are shown in figure 7. At low speeds the model ran much as a displacement body with only slight variation in trim and rise. At a full-scale speed of about 40 miles per hour, the model increased trim and rose abruptly as the skis emerged from the water. From this speed to take-off the model planed on the hydro-skis. The speed at which the hydro-skis emerged is indicated in figure 7. Once the hydro-skis had emerged, it was possible to reduce speed substantially before they resubmerged. When the hydro-skis emerged, a high trim was obtained largely because the flow of the water over the curved rear of the fuselage sucked the tail down. With the high trims maintained by this suction, the hydro-skis provided sufficient lift to support the model at a speed substantially lower than the speed of emergence and thus the hysteresis in the curves of figure 7 was obtained. Such hysteresis tends to insure that hydro-skis will continue to plane once they have emerged.

Below the speeds at which the hydro-skis emerged, it was not practicable to operate the model with the flaps down because of the hydrodynamic diving moment that they produced. When the hydro-skis were planing, there was little difference between the curves for flaps up and flaps down, except very near take-off where the reduction in take-off speed caused by lowering the flaps showed to advantage. For minimum take-off time and distance, it would be desirable to lower the flaps at some convenient time after the hydro-skis emerge.

The maximum resistance shown in figure 7 is quite high compared with the resistance of conventional seaplane floats. There is no reason to assume that the hydro-ski configuration tested for take-off approaches an arrangement that would give optimum resistance. Hence, it is probable that hydro-ski configurations having substantially lower resistance can be found by suitable investigation. It should be noted that the resistance curves in figure 7 include the air drag of the complete model.

No porpoising was encountered in any of the test runs or in the accelerated runs that were made. No instabilities of any sort were observed with the elevator deflection used.

Up to the speed at which the hydro-skis emerged, the wing served as a hydrodynamic component. At rest the wing tips were slightly submerged (fig. 3) and at 35 miles per hour (full size) the wings planed on the water (fig. 6).

At about 30 miles per hour (full size) heavy spray tended to come near the proposed turbojet intake locations shown in figure 1. Small $\left(\frac{3}{4}\text{-inch square full-size}\right)$ strips placed along the streamlines near the nose were effective in reducing the spray that came near the jet intakes.

PRACTICAL CONSIDERATIONS

These preliminary tests have disclosed no serious obstacles to the use of hydro-skis to provide a means for landing and taking off high-speed jet-propelled airplanes. The indications are that the hydro-skis will function satisfactorily in any reasonably sheltered body of water. The maximum size of waves that would be tolerable has not yet been determined.

It would be desirable to obtain configurations with less resistance than the one presented and further research toward this end should be of value. One obvious approach towards reducing resistance would be to provide camber on the upper surface of the hydro-skis. Nevertheless, when considering the use of hydro-skis on an airplane provided with a liquid-propelled rocket, a high resistance may in many cases be tolerated without penalty to the performance in the air. Any fuel used for take-off will not be a part of the flying weight and, insofar as flight load factors are concerned, it should not be included in the gross weight. Of course, extra tank space for the take-off fuel would be required but, if this imposes any considerable additional weight or volume, it could be made jettisonable.

The proper location of jet intakes on water-based airplanes is a subject of prime interest in considering applications of hydro-skis. It should be possible to obtain locations acceptable for both take-off and flight in most cases. However, for some applications, it may be advantageous to provide alternate intakes for take-off. This should be relatively simple because at speeds below take-off the amount of ram is so small that it need not be considered in locating the take-off intake; thus, air can be taken from any convenient area not subject to excessive spray.

In the hypothetical airplane of the present tests the rocket exhaust is placed below the turbojet exhaust, which is located above the water line at rest. (See reference 1.) In such an installation it would probably be advisable to provide for closing of the turbojet exhaust opening when the airplane is at rest in order to prevent water from washing into the opening. Rocket motors have been successfully exhausted under water in experimental take-offs of a flying boat so that this part of the exhaust arrangement should cause no insurmountable difficulties.

The practicability of using the wing as a hydrodynamic component must depend on the type of wing construction and the maximum speed at which the wing is allowed to plane on the water. The wing can probably be made to clear the water at a lower speed than that shown in the tests. However, because of the necessity for increasing the strength of airplane wings as airplane speeds are increased and because the wing would not be directly subject to landing impact loads, its use as a hydrodynamic component to the extent indicated by the present tests looks feasible.

A number of hydro-ski configurations appear to be of interest. Considering the variation in the under surfaces of airplane fuselages and wings, there is considerable variation in the type of surface that can be flush retracted. Triple-ski or quadruple-ski arrangements may prove to be useful. If lateral stability can be maintained at speeds above the hydro-ski emergence speed, a single hydro-ski may be practicable.

Where the utmost in flying performance is desired, a part of the hydro-skis could be jettisoned after take-off since the landing could be made with hydro-skis of smaller size than take-off requires. This procedure might be justified to provide for special overloads or take-offs in areas of limited lengths.

CONCLUDING REMARKS

The data given in this paper show that retractable planing surfaces (hydro-skis) placed below a dynamic model of a transonic airplane enable the model to take-off and land stably on the water. The high water resistance obtaining during take-off, although not necessarily inherent in hydro-skis, appears to be acceptable for jet-propelled aircraft through the use of auxiliary fuel tanks. Further research aimed at reducing this resistance, nevertheless, is warranted. Consideration of other problems incidental to practical applications of hydro-skis leads to the conclusion that solutions for these problems can be obtained. Thus, it appears that hydro-skis suitable for flush retraction into streamline fuselages offer a practicable means for taking off and landing high-speed airplanes on the water.

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REFERENCE

1. King, Douglas A.: Tests of the Landing on Water of a Model of a High-Speed Airplane - Langley Tank Model 229. NACA RM No. L7I05, 1947.

[redacted]

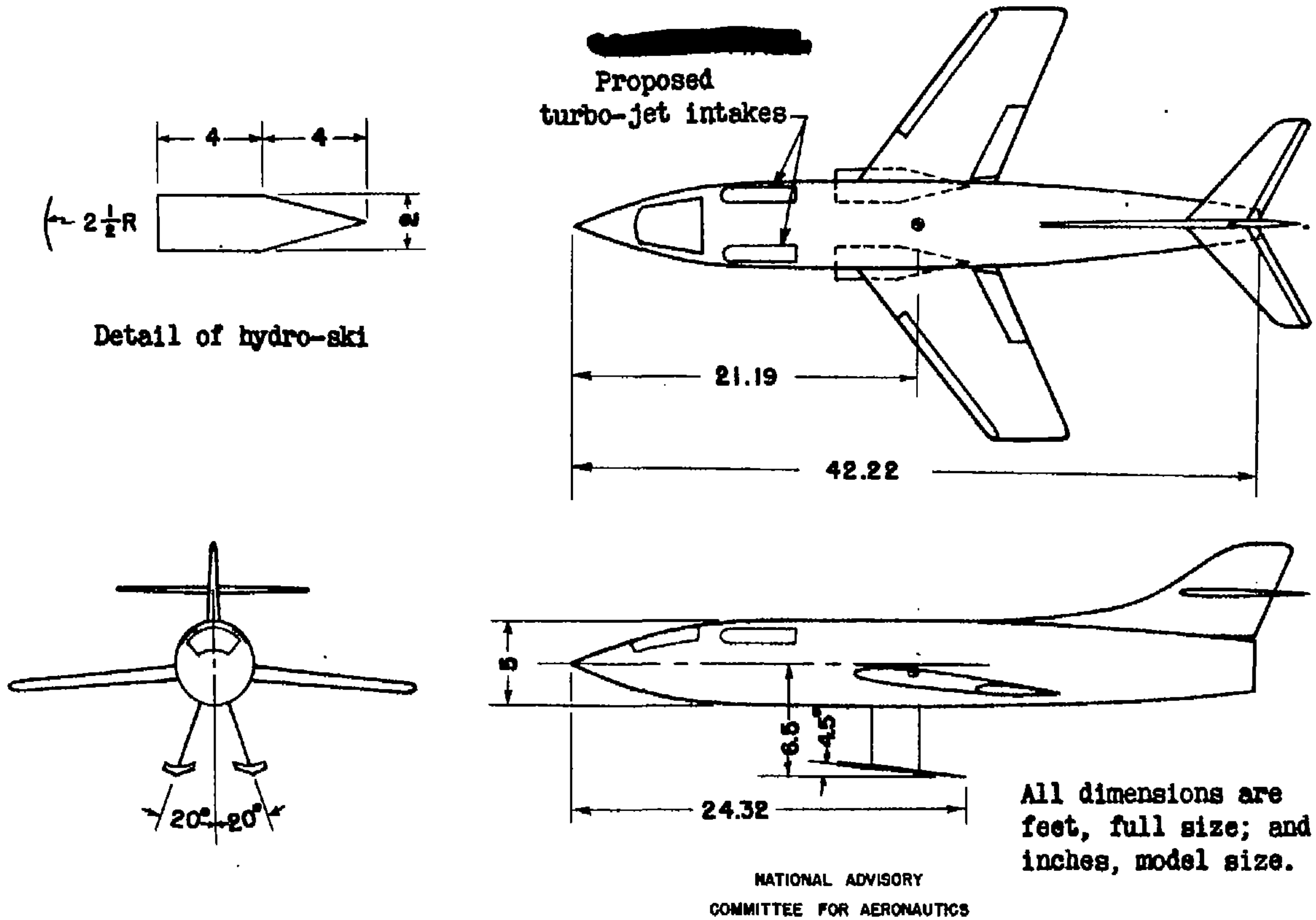

Figure 1.- Drawing of model fitted with NACA hydro-skis.

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[redacted]

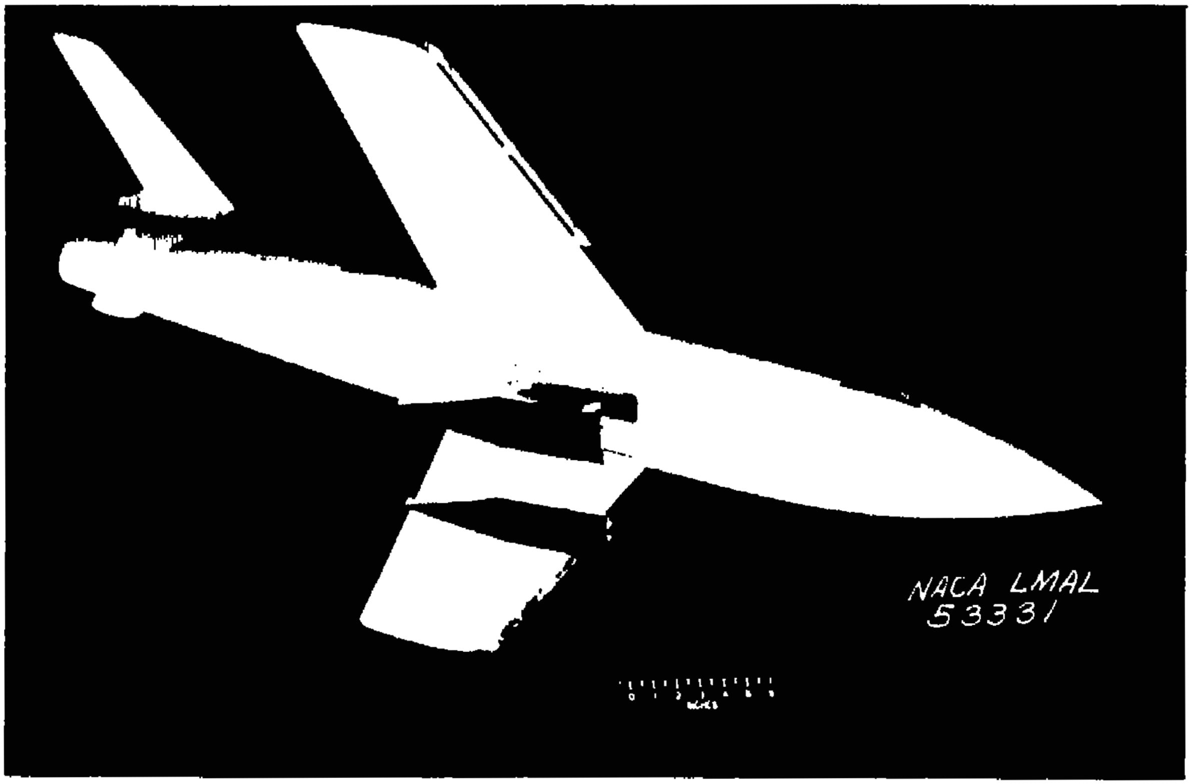

Figure 2.- Photograph of model fitted with NACA hydro-skis.

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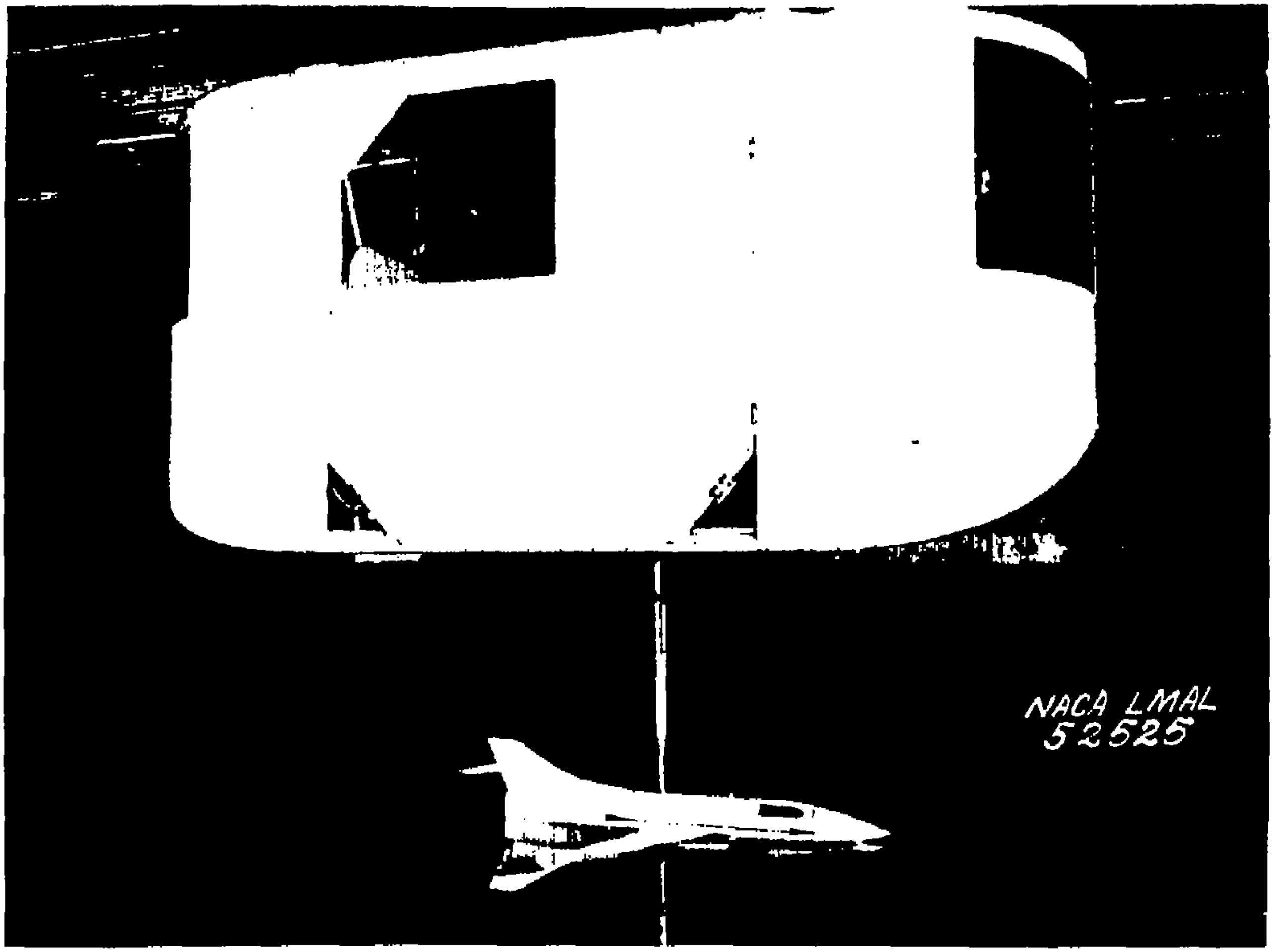

Figure 3.- Take-off test setup showing model floating at take-off weight.

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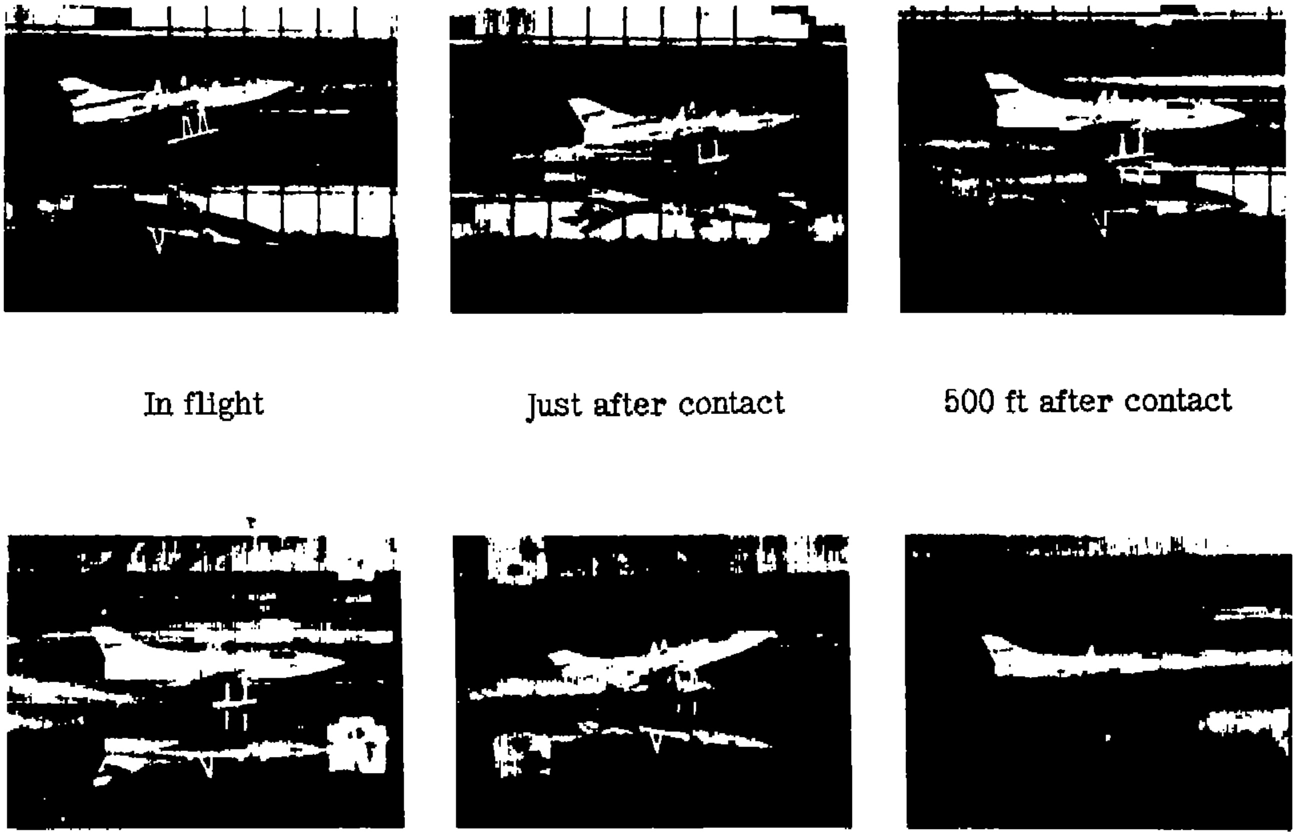

In flight

Just after contact

500 ft after contact

1330 ft after contact

2330 ft after contact

2380 ft after contact

Figure 4.- Sequence photographs of typical landing run. (Distances are full-size.)

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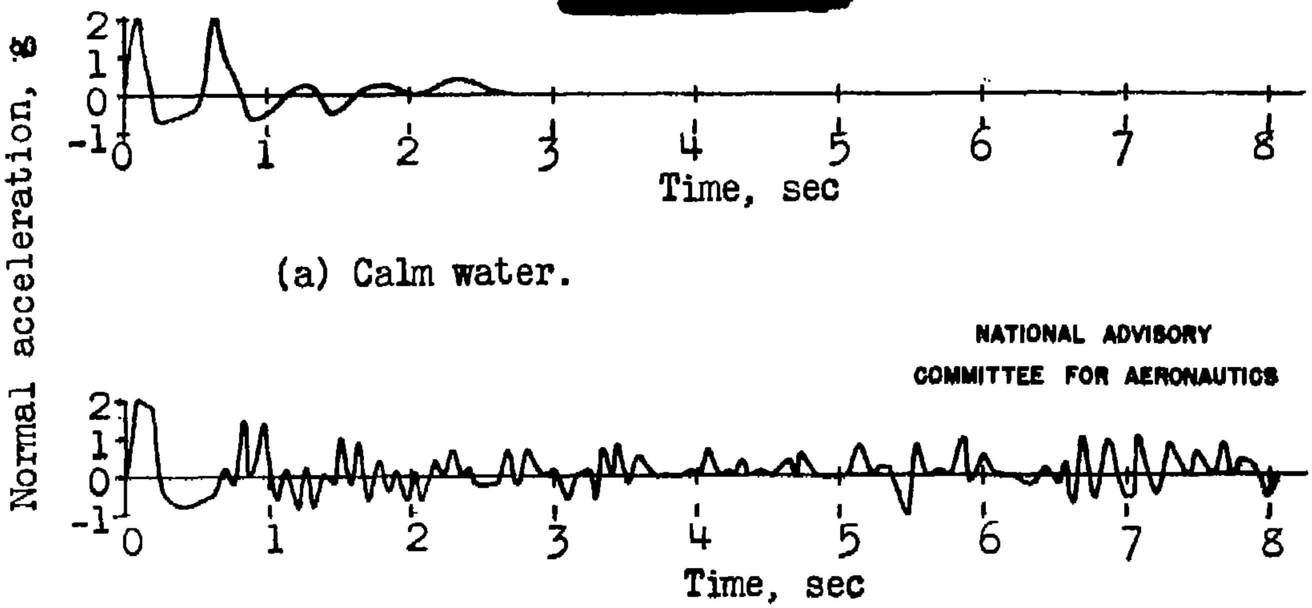


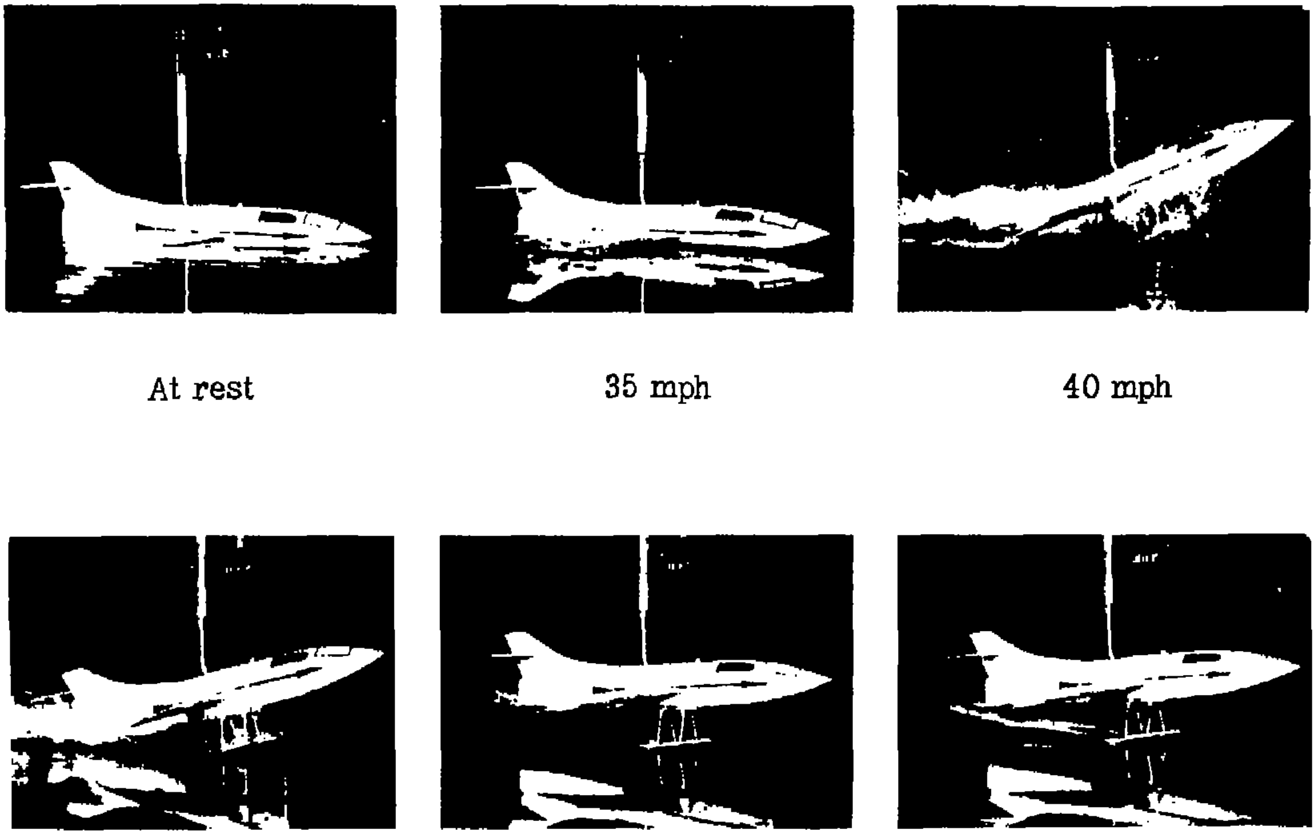
(a) Calm water.

(b) Rough water, waves 1.5 feet high.

[redacted]

Figure 5.- Normal accelerations in calm and rough water.

[redacted]



At rest | 35 mph | 40 mph

60 mph | 105 mph | 130 mph

Figure 6.- Sequence photographs of typical take-off run. (Speeds are full-size.)

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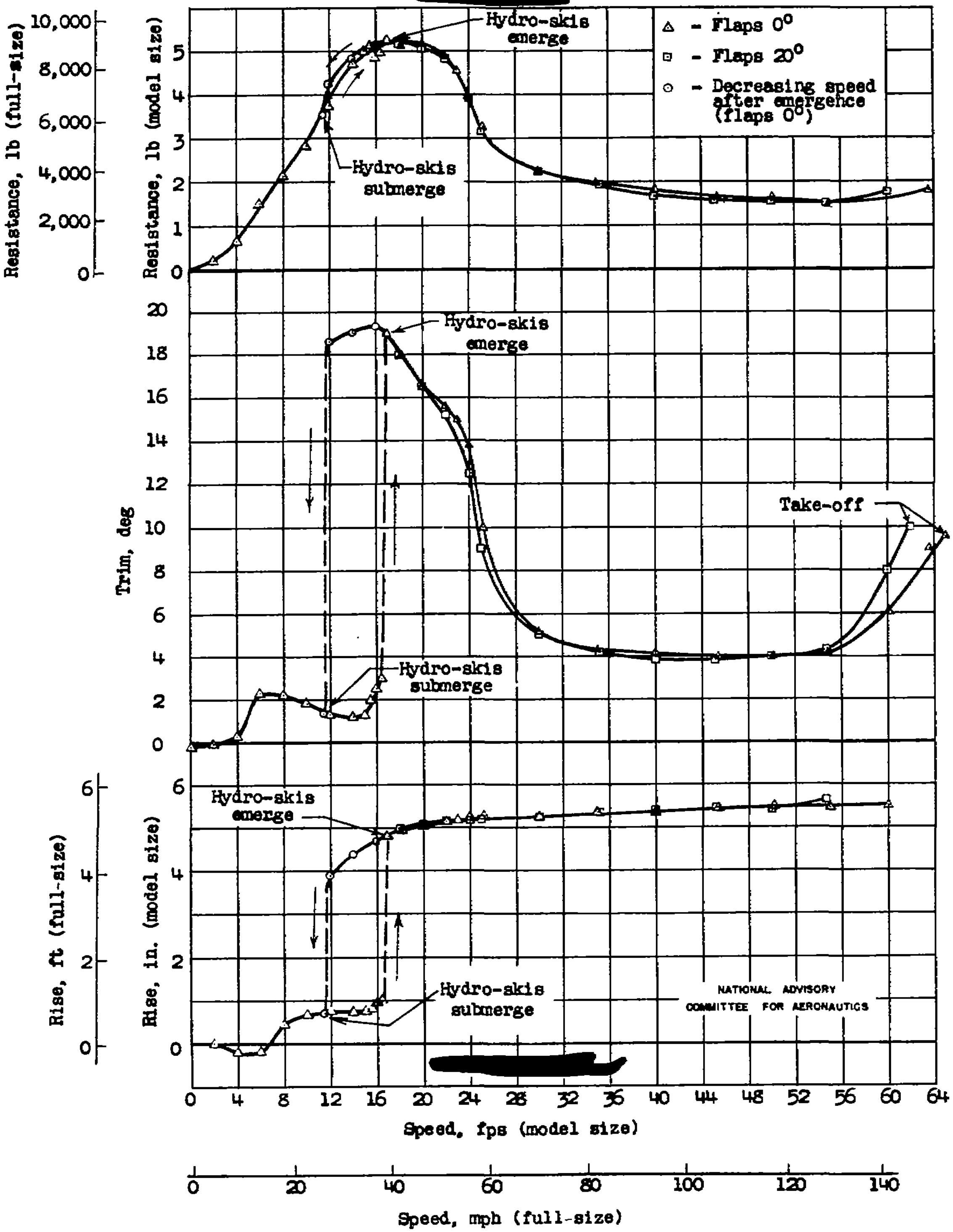

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Figure 7.- Resistance, trim, and rise.